IDAHO
FISH & GAME DEPARTMENT

John R. Woodworth, Director

FEDERAL AID IN FISH AND WILDLIFE RESTORATION

JOB COMPLETION REPORT

Project F-49-R-7

SALMON AND STEELHEAD INVESTIGATIONS

Job No. 5. Embryo Survival and Emergence Studies

Job No. 7. Spawning and Emergence of Chinook Salmon as Related to Temperature

By

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December, 1969

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JOB COMPLETION REPORT

RESEARCH PROJECT SEGMENT

State of Idaho

Project No. F-49-R-7

Job No. 5

Name: SALMON AND STEELHEAD INVESTIGATIONS

Title: Embryo Survival and Emergence Studies

Period Covered: March 1, 1968 to February 28, 1969

ABSTRACT:

The survival and emergence of steelhead trout (Salmo gairdneri) and chinook salmon (Oncorhynchus tshawytscha) in gravel with various amounts of granitic sand were tested in troughs with flow and gradient control. Chinook salmon fry readily emerged from gravel with less than 20 percent sand, experienced difficulty in 20-40 percent sand, and few emerged from more than 40 percent sand. Most steelhead trout fry emerged from gravel with up to 30 percent sand, half emerged with 50 percent sand and only 10 percent emerged with 55 percent sand.

Sand in spawning gravel also reduced the flow of water through the gravel and created lethal conditions of low oxygen or high waste concentrations that caused large mortalities in troughs with 20 percent or more sand and spring water. In tests with spring and creek water mixed (higher initial oxygen content) the mortalities were less than with only spring water.

Mortalities of 60-80 percent of chinook salmon and 40-60 percent of steelhead trout embryos may occur when sufficient sand is present to fill the gravel interstices (30-40 percent sand). High egg to emergent fry survival is desirable as fewer adults are needed to adequately seed a rearing area.

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RECOMMENDATIONS:

Additional tests of this nature are not necessary at this time. OBJECTIVES:

To determine the effects of various proportions of fines in spawning gravel on the survival and emergence of salmon and trout.

TECHNIQUES USED:

Test Facilities

The same facilities (Figure I) used in the 1967 tests (Bjornn, i969) were also used in the 1968 tests. Gravel composition was also the same.

Test Procedures

Steelhead trout. Two tests were conducted with steelhead trout in 1968: (1) green eggs placed in the gravel of 32 troughs to assess survival through incubation and emergence, and (2) swim-up fry placed in the gravel of 32 troughs to assess the effects of gravel-sand mixtures on emergence.

Green steelhead eggs placed in troughs E, F, G, and H on May I, 1968, died within a few days from the shock of handling. The troughs were cleaned and 135-i37 eggs were placed in troughs (E-H) on June 13. These eggs were handled in a different manner when placed in the gravel and mortality due to handling was much reduced.

Fifty swim-up fry were placed in troughs A-D on July 27. Trapping of the fry as they emerged began on July 28 in both the swim-up fry and green-egg troughs. All fry were measured as they were captured to compare mean lengths of fish from various gravel-sand mixtures.

Spring water, 54°F, 4-5 ppm dissolved oxygen, was supplied to all the troughs. The gradient was set at 2 percent.

Chinook salmon. Two tests were also conducted with chinook salmon in 1968: (I) green eggs and (2) swim-up fry. The objectives were the same as in the steelhead tests.

On August 31, a total of 110 green chinook eggs were placed in troughs E-H. A mixture of Hayden Creek and spring water was used in these tests to increase the concentration of dissolved oxygen. Water entering the test troughs contained 6-8 ppm dissolved oxygen and ranged from 46-50^0 F.

The swim-up fry tests were initiated December 5, and 50 fry were placed in each A-D trough. A mixture of spring and Hayden Creek water was supplied to these troughs. Trapping of the fry began on December 6.

FINDINGS:

Steelhead trout

Nearly all (92 percent) swim-up fry placed in the troughs with 30 percent or less and emerged with little difficulty (Table I). At 48 percent sand only half the fry

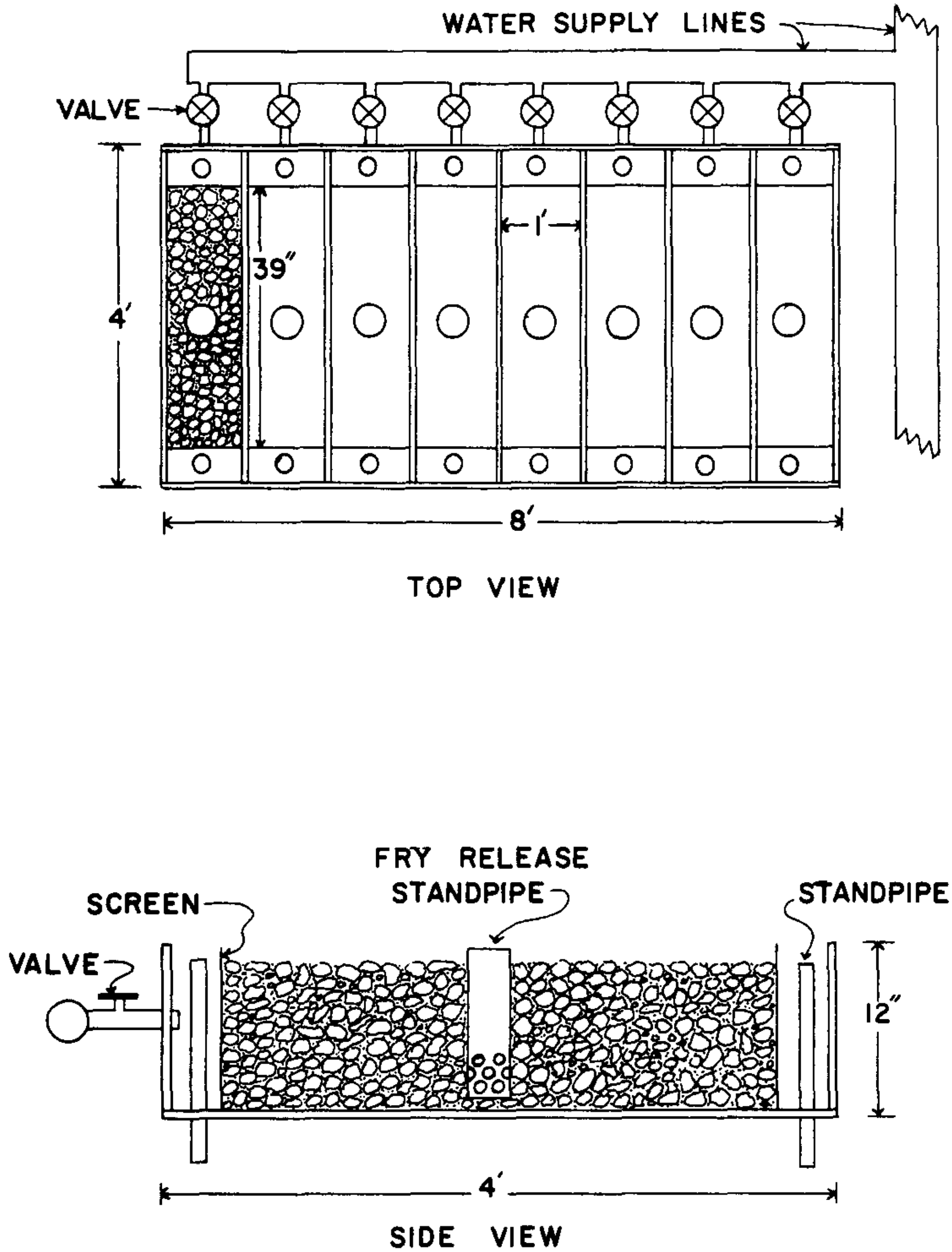

Figure 1. Troughs used in embryo survival and emergence tests.

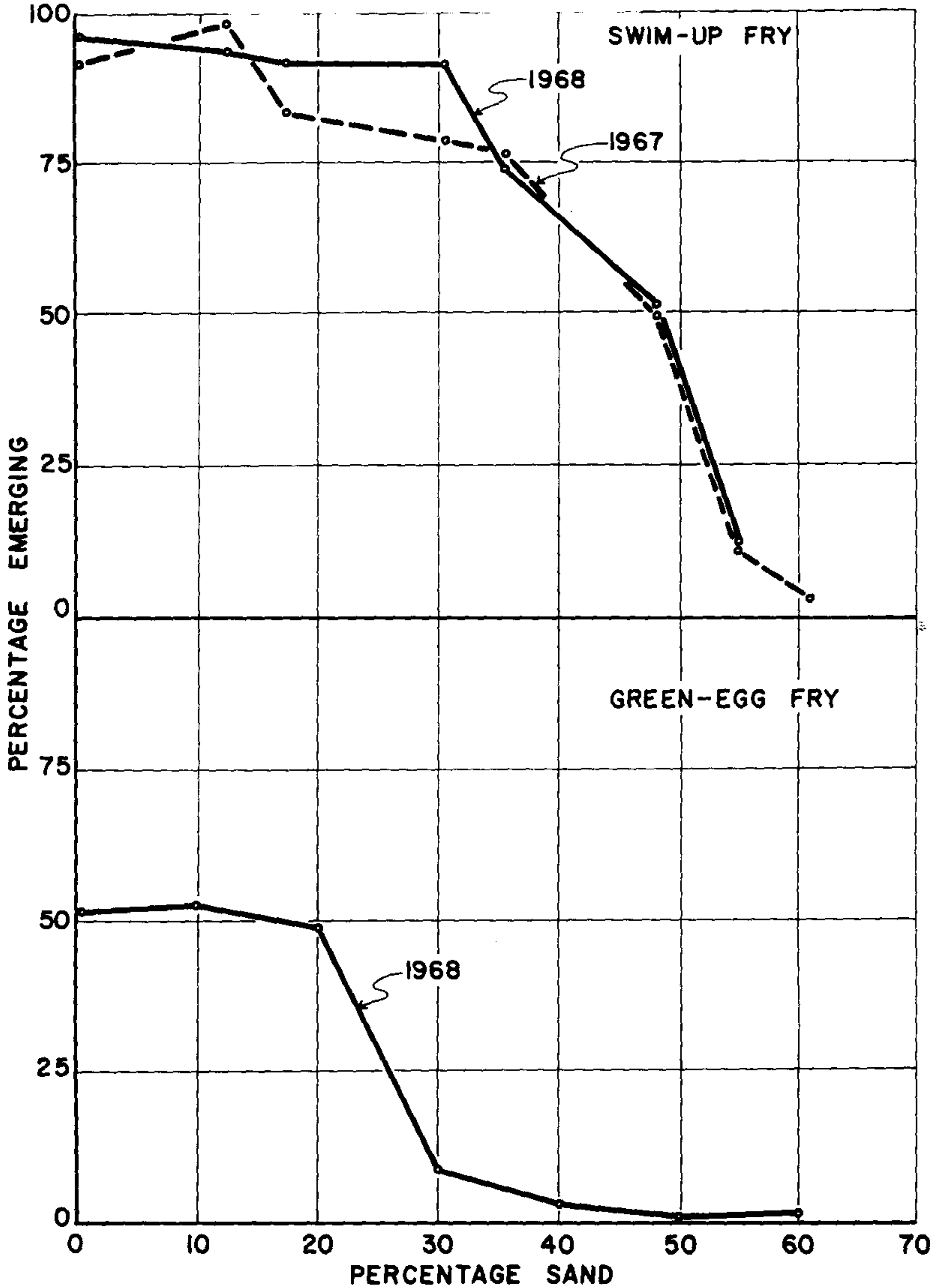

Figure 2. Percentage of steelhead trout swim-up fry or green eggs placed in troughs that emerged as fry. Each point the mean of four replicates.

Table I. Number and percentage of steelhead trout fry emerging from gravel-sand mixtures. Fifty swim-up fry placed in each trough.

Percentage sand	Trough number	Fry emerging	Mean percentage emerging
0	A3, A6, A7, B8	47, 50, 47, 48	96.0
12	A1, A2, C1, C8	49, 46, 45, 47	93.0
17	C6, D1, D3, D7	46, 48, 46, 45	92.5
31	A4, B5, C5, D5	45, 48, 44, 47	92.0
36	B6, C3, C4, D8	37, 35, 33, 43	74.0
48	A5, B2, B4, D2	38, 3, 36, 26	51.0
55	B1, B7, C7, D6	13, 8, 0, 3	12.0

Table 2. Number and percentage of steelhead trout try emerging from gravel-sand mixtures. One hundred thirty-six green eggs placed in each trough.

Percentage sand	Trough number	Fry emerging	Mean percentage emerging
0	E3, E6, E7, F8	71, 68, 58, 86	52.0
10	E1, E2, G1, G8	69, 80, 72, 67	52.9
20	G6, H1, H3, H7	47, 82, 79, 62	49.4
30	E4, F5, G5, H5	2, 4, 9, 32	8.6
40	F6, G3, G4, H8	0, 2, 4, 11	3.1
50	E5, F2, F4, H2	0, 1, 1, 5	1.3
60	F1, F7, G7, H6	0, 0, 9, 0	1.7

emerged and only 12 percent emerged from troughs with 55 percent sand. The results of the 1968 tests with swim-up fry were nearly identical with results of the 1967 tests (Figure 2) (Bjornn, 1969).

The survival and emergence of steelhead fry from green eggs placed in the troughs were less than the emergence of the swim-up fry (Table 2). In troughs with 0 or 12 percent sand the fry captured represented only half the eggs placed in the troughs. If we can assume from the swim-up fry tests that nearly all live fry could emerge from gravel with little or no sand then the 50 percent loss probably occurred during the incubation, hatching, and yolk-sac stages. The causes of the loss were not determined but could be a combination of handling, low oxygen (4-5 ppm), toxic materials in water supply (zinc, 00_2) and natural causes.

In troughs with 30 percent or more sand the fry which emerged represented less than 10 percent of the eggs planted (Table 2). A combination of low oxygen levels and reduced flows in the troughs with enough sand to fill the interstices resulted in increased mortality during the incubation stage.

There was no significant difference in length of fry from the various troughs planted with green eggs.

Chinook salmon

In 1968 a high percentage of the swim-up fry placed in the troughs with less than 20 percent sand emerged from the substrate (Table 3). Healthier fry were used in the 1968 tests compared to 1967. As in 1967, few fry emerged from the troughs with 40 percent or more sand (Table 3 and Figure 3).

In the 1968 tests with green eggs, 70 percent of the eggs survived to emerge as fry from the troughs with 10 percent or less sand (Table 4). With increasing percentages of sand over 10 percent a decreasing percentage of the eggs survived to emerge as fry.

In the 1967 tests, few of the green eggs in troughs with 20 percent or more sand survived to emerge (Figure 3). The reason for the abrupt decline in percentage of fry emerging in 1967 may have been the relatively low dissolved oxygen concentrations (4-5 ppm) of the spring water entering the troughs. The low oxygen concentrations plus reduced flows due to the sand in the gravel may have created lethal conditions in troughs with 20 percent or more sand.

In the 1968 tests with green eggs we tried to alleviate the low oxygen concentration problem by adding Hayden Creek water. With the creek water, oxygen concentration of water entering the troughs increased to 6-8 ppm and temperatures were reduced. The percentage of eggs emerging as fry in the 1968 tests also decreased as sand increased above 20 percent but the decline was not abrupt (Figure 3).

The fate of the green eggs (30 percent of total) which did not survive to emerge as fry in the troughs with 10 percent or less sand was not determined. Mortality was probably due to handling and/or natural causes.

DISCUSSION:

Large amounts of granitic sand (<1/4" diameter) in spawning gravels can (i) impede movement of fry making emergence difficult and (2) reduce the flow of water through the gravel thereby reducing the amount of dissolved oxygen passing the embryos

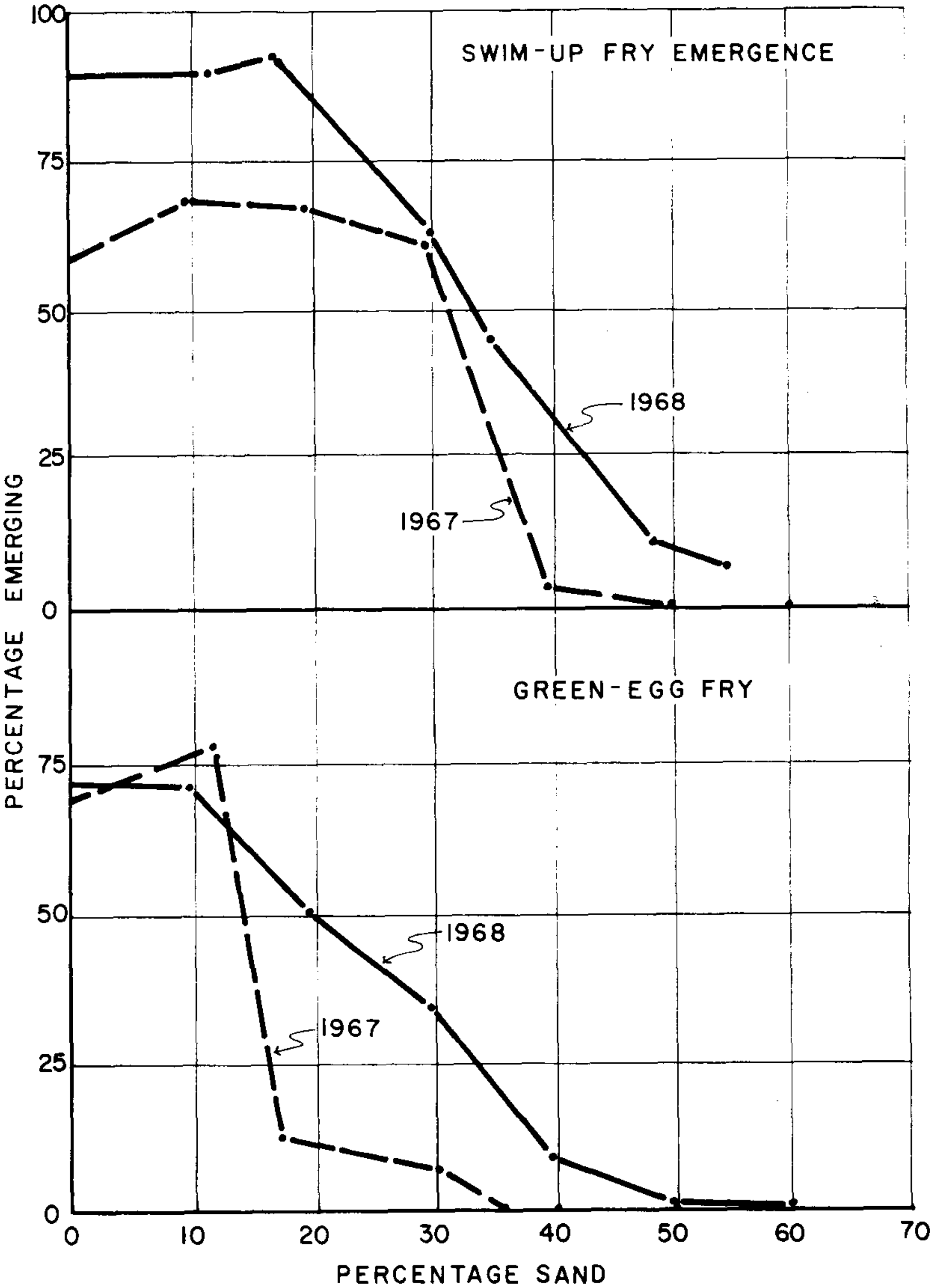

Figure 3. Percentage of chinook salmon swim-up fry or green eggs placed in troughs fhat emerged as fry. Each point the mean of four replicates.

Table 3. Number and percentage of chinook salmon emerging from gravel-sand mixtures. Fifty swim-up fry placed in each trough.

Percentage sand	Trough number	Fry emerging	Mean percentage emerging
0	A3, A6, A7, B8	41, 38, 46, 53	87.7
12	A1, A2, C1, C8	43, 46, 39, 50	89.0
17	C6, D1, D3, D7	44, 43, 47, 52	92.1
31	A4, B5, C5, D5	38, 27, 9, 50	62.0
36	B6, C3, C4, D8	12, 39, 37, 1	44.5
48	A5, B2, B4, D2	8, 1, 2, 10	10.5
55	B1, B7, C7, D6	13, 0, 0, 0	6.5

Table 4. Number and percentage of chinook salmon fry emerging from gravel-sand mixtures. One hundred ten green eggs paced in each trough.

Percentage sand	Trough number	Fry emerging	Mean percentage emerging
0	E3, E6, E7, F8	93, 71, 88, 59	70.7
10	E1, E2, G1, G8	58, 82, 87, 85	70.9
20	G6, H1, H3, H7	50, 63, 57, 49	49.8
30	E4, F5, G5, H5	23, 15, 56, 53	33.4
40	F6, G3, G4, H4	5, 23, 0, 11	8.9
50	E5, F2, F4, H2	0, 0, 6, 1	1.6
60	F1, F7, G7, H6	0, 0, 4, 1	1.1

and the transport of waste materials *away* from the embryos.

The tests conducted with swim-up fry in 1967 and 1968 were designed to measure the effect of sand on only the emergence of fry. Chinook salmon fry readily emerged from spawning gravel with less than 20 percent sand. Fry had difficulty emerging from gravel with 20-40 percent sand and few fry emerged from gravel with all the interstices filled with sand (>30-40 percent sand) (Figure 3).

Steelhead trout fry emerged from gravel with higher percentages of sand more readily than chinook salmon. Slightly reduced numbers of steelhead fry emerged at 30-40 percent sand and almost half the fry emerged from troughs with 50 percent sand (Figure 2). Although more steelhead than chinook fry emerged from gravel with the interstices filled with sand (30-40 percent sand) a reduction in emergence occur-red (in both species).

The tests with green eggs were designed to measure the effects of sand on both emergence and survival during the pre-emergence stage. The fry that emerged in the green-egg tests survived test-induced mortality factors (handling, reduced water flow in gravel, and impeded movement due to sand) and natural mortality factors (adult to egg transmitted disease, deformities, etc.). In the troughs with little or no sand (<10 percent sand) the embryos which did not survive probably succumbed to handling and natural mortality since there was not enough sand in those troughs to reduce water flow or impede movement. Mortality in troughs with more than 10 percent sand occurred from a combination of test and natural causes.

A measure of mortality caused only by reduced flow and impeded movement in the green egg tests was obtained by adjusting the percentage emerging in the green egg tests upward to equal the percentage emerging in the swim-up fry tests in the troughs with no sand. For example, the 52 percent emergence of steelhead fry in zero sand was multiplied by a factor of 1.81 which resulted in an adjusted value of 94 percent, the same as emergence for swim-up fry. Each percentage emergence value in the green egg test was multiplied by the factor. By adjusting the percentage emerging values for the green-egg tests I theoretically removed the mortality due to handling and natural causes. The adjusted percentage values for the green-egg tests therefore represent fry which survived the reduced flow and impeded movement condition imposed by the test, and conversely those which did not emerge succumbed to conditions resulting from reduced water flow and/or impeded movement.

The emergence curves for fry which only had to emerge (swim-up fry tests) versus those which had to survive incubation and emerge (green-egg tests) began to diverge when the percentage sand in the gravel exceeded 10 percent in the case of chinook salmon and 20 percent in the case of steelhead trout (Figure 4). The difference between the emergence only (swim-up *fry)* and survival and emergence (green egg) curves theoretically represents the percentage of fry which succumbed to conditions in the gravel associated with reduced flow of water.

In the 1967 chinook tests and 1968 steelhead tests the green-egg survival and emergence curves differed markedly from the swim-up fry emergence curve possibly due to the relatively low concentration of dissolved oxygen of spring water entering the troughs (4-5 ppm). The reduced flow caused by 20-30 percent sand may have been sufficient to create oxygen deficient conditions in the gravel where the embryos were incubating.

In the 1968 chinook salmon tests I tried to eliminate any effect of low oxygen concentrations in the water supply by adding Hayden Creek water to the spring water.

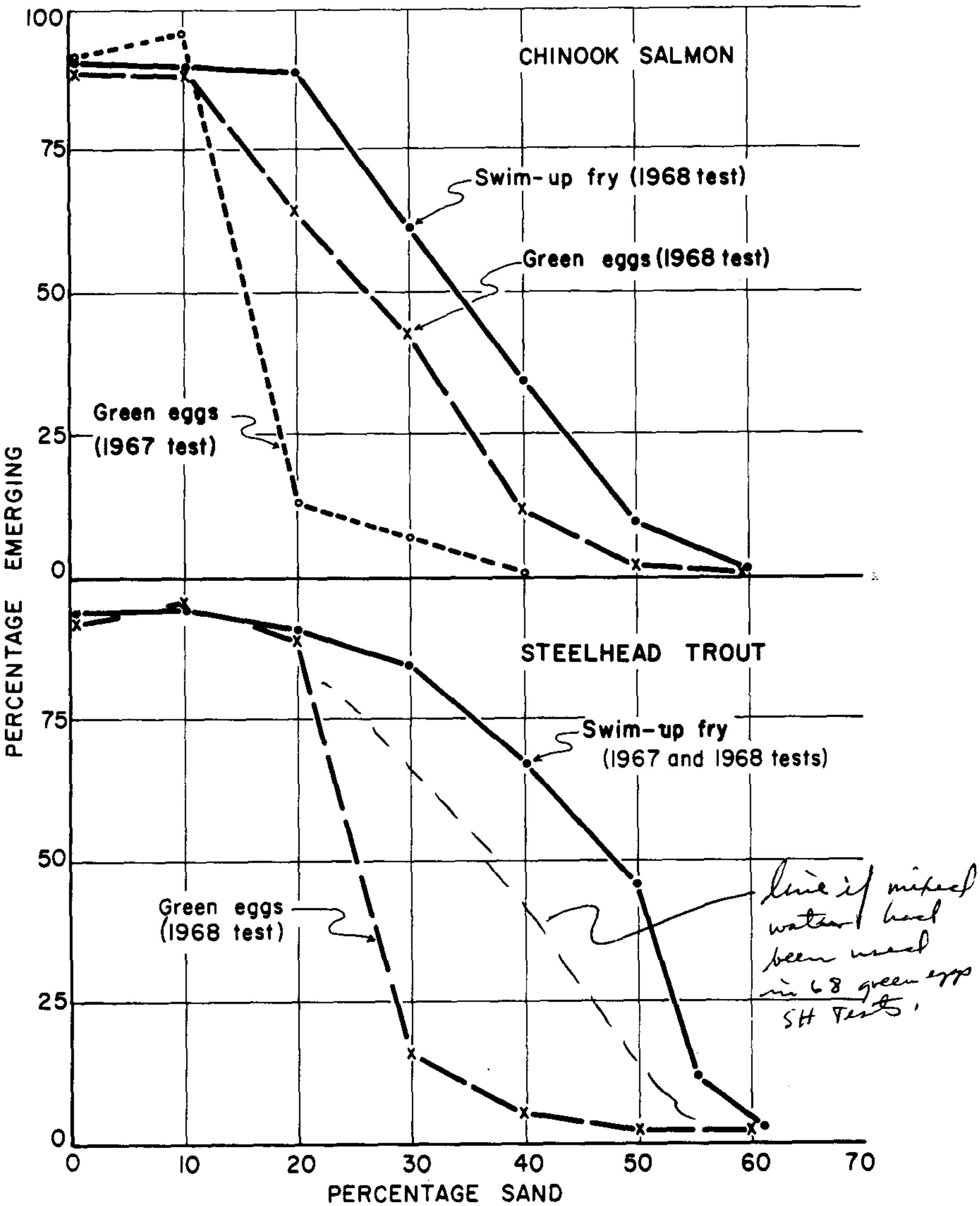

Figure 4. Percentage of steelhead trout and chinook salmon emerging
from gravel in troughs. Green-egg points adjusted to comp
ensate
for mortality due to causes other than test conditions.
Pefer to text for explanation

The survival and emergence (green egg) curve which resulted trom this tesf paralleled the swim-up fry emergence curve after an initial drop between 10 and 20 pe'cent sand (Figure 4). In the 1968 tests in addition to the fry which could not emerge because of restricted movement due to sand an additional 20-30 percent did not survive and emerge perhaps because of conditions associated with reduced water flow. i believe the 1968 survival and green-egg emergence curve for chinook salmon (figure 4) better approximates reduced flow and impeded movement mortality in natural streams than the curve from 1967 green egg tests.

In summary, embryo mortality in gravel with 30-40 percent sand (interstices filled) due to reduced water flow and inabiiity to emerge from the gravel may approach 75 percent in the case of chinook salmon and 30-50 percent in the case of steelhead

ACKNOWLEDGEMENTS:

The folowing persons participated in these tests and their help is appreciated: Delbert Ledington, Dean Meyers, Melvin Reingold, and Rudy Ringe.

LITERATURE CITED:

Bjornn, T. C. 1969. Embryo survival and emergence studies, Job No. 5. Salmon and Steelhead Investigations Project No. F-49-R-6. Annual completion report. Idaho Fish and Game Depf., 9 pp.

JOB COMPLETION REPORT RESEARCH PROJECT SEGMENT

State of Idaho

Name: SALMON AND STEELHEAD INVESTIGATIONS

Project No. F-49-R-7

Title: Spawninq and Emergence of Chinook Salmon as related to temperature

Job No. 7

Period Covered: March I, 1968 to February 28, 1969

ABSTRACT:

Tests were conducted to determine if newly emerged chinook salmon (Oncorhynchus tshawyschus) fry moved downstream more readily in cold water, and if cold water (C $^{-}44^{0}$ F) would delay emergence. Eighty-two percent of the fry in the coldest water (36-37° F) moved downstream after emergence compared to 50-60 percent in warmer waters. Fry placed in cold water emerged at a slower rate than fry placed in warmer water; however, I do not believe emergence is delayed more than 5-10 days by cold water temperatures.

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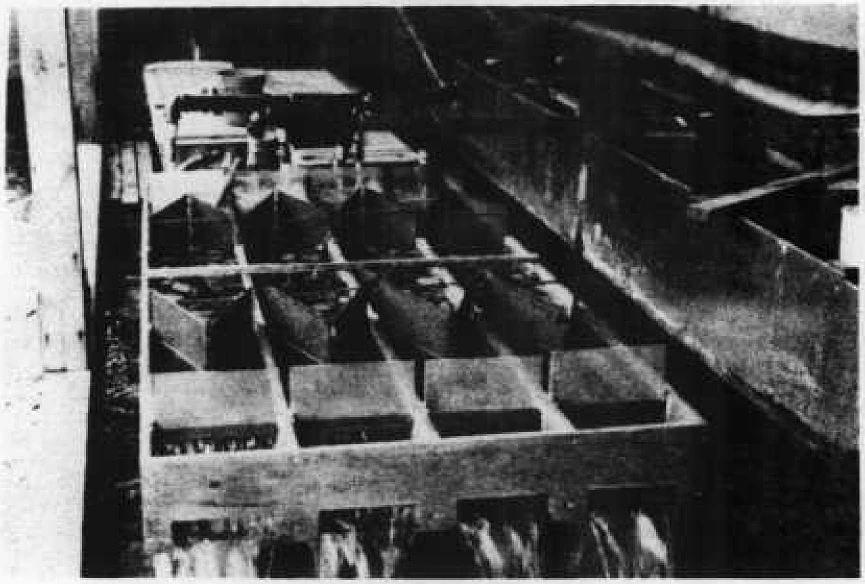

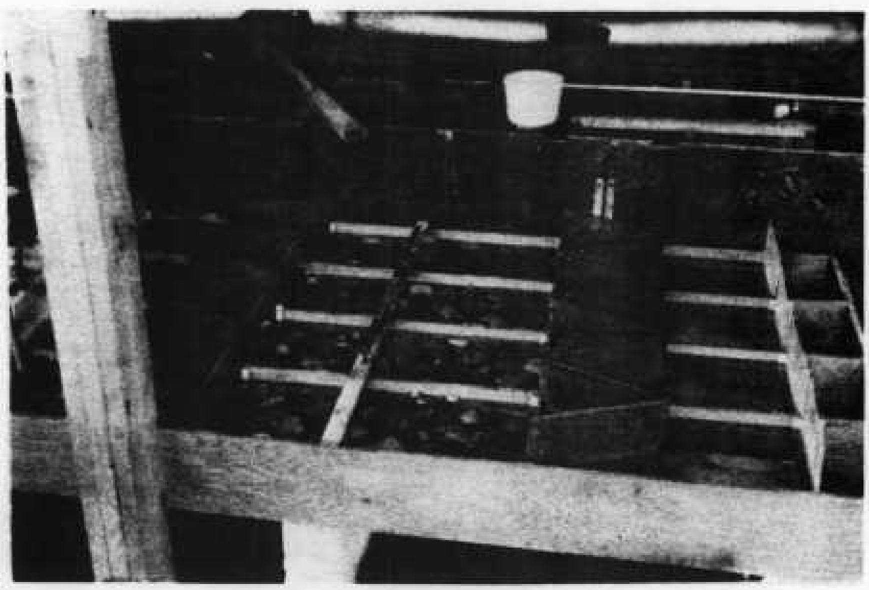

Figure 1. Test troughs used to evaluate salmon fry emergence and movement as related to temperature.

RECOMMENDATIONS:

Follow-up studies to determine the amount of interaction between spring and summer chinook salmon fry should be conducted to obtain information needed to properly manage spring and summer chinook in areas where both are present.

OBJECTIVES:

To determine rate of emergence and direction of movement after emergence or chinook fry in various water temperatures-

TECHNIQUES USED:

Swim-up chinook salmon try f-cm Hayden Creek Hatchery were introduced into a test trough with four sections Figure „ Each section was identical except for temperature of the water flowing through each channel. I mixed Hayden Creek and spring water to obtain temperafures in the channel s of 36-370, 40-44°, 47-49°, and 54° F.

Fry were introduced into fhe gravel of the channels through 2 inch diameter plastic pipes with one-half inch diameter perferations in the lower 3 inches. After the fry emerged They were caught in V-type traps at either end or the channels depending on the direction of movement.

Four tests conducted during December and January required 10-12 days each for most fry to emerge and migrate. The wafer was shut off and troughs cleaned between each test.

FINDINGS:

In the test facilities used, a majority of The try *were* captured in the *down*-stream traps in all but 5 of 16 replications, however, 2-3 times more try entered upstream traps in 400 F or warmer water compared to the channel with 36-370 F water (Table I). The results of these tests were similar to the results of tests by Miller (University of Idaho unpublished data on direction of try movement as related to temperature) and my observation or fry movements in streams or the Salmon River drainage.

The cold water Temperafures normaly present when most chinook salmon try emerge probably contribute to an increased number or fry moving downstream. As temperatures warm in the spring the number of downstream migrants decreases.

Fry emerged at a slower rate in channels with code- water (figure 2). Nearly all fry emerged within 10-12 days in 36-370 F water compared to 3-4 days at 54° F.

I have observed chinook fingerling (after first summer) enter and stay in the substrate of streams when temperatures dropped below 40-420 F. wondered if this tendency to enter the substrate in older fish would cause fry to delay emergence if the water was less than 450 F. Although Try in the channel with coldest water emerged at a slower rate than fry in warmer waters, *fr*om the results of these tests and observations in the field, ! do not believe emergence is significantly delayed because of cold water.

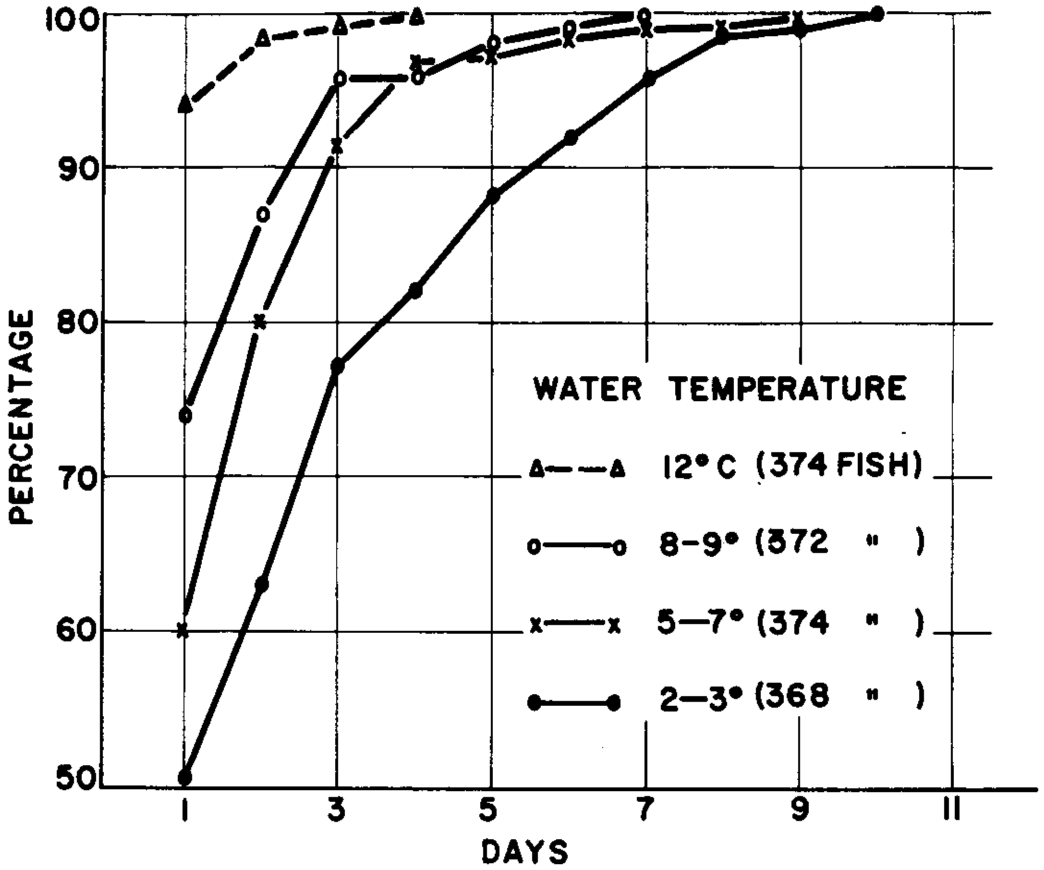

Figure 2. Cumulative percentage of salmon fry emerging and entering traps in test troughs each successive day after test initiated. Each point is the mean of 4 tests at each temperature.

Table I. The number of newly-emerged chinook salmon fry moving up- or downstream after being placed in channels with various water temperatures. Percentage in parentheses.

Direction of movement	Test number	Water temperature °f 36-37	40-44	47-49	54
Up	I	3	20	21	23
	2	17	33	62	51
	3	10	17	23	3
	4	37	66	91	88
	Mean	16.8(18)	34.0(36)	49.3(53)	41.3(44)
Down	I	80	50	55	53
	2	76	68	28	'47
	3	90	83	79	97
	4	59	36	9	12
	Mean	76.2(82)	59.3(64)	42.8(47)	52 3(56)

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